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Ph.D. DISSERTATION DEFENSE

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Degree: Doctor of Philosophy

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Department of Mechanical Engineering

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McLean 414

Title: Design, Modeling, and Control of Low-Cost Underwater Vehicle-Manipulator Systems

Chairperson: Dr. Long Wang, Department of Mechanical Engineering, SES

Committee Members: Dr. Brendan Englot, Department of Mechanical Engineering, SES
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ABSTRACT

Underwater robotics is an under-researched field due to various barriers to entry, including the harsh environment, expensive hardware, and complex control challenges. Nevertheless, underwater robots hold significant value due to their ability to perform surveying and intervention tasks in environments that are hazardous and inaccessible to humans. This dissertation presents four novel contributions aimed at lowering these barriers through the development of low-cost and open-source underwater robot manipulator designs, along with advancements in modeling, planning, and control.

The first contribution is the novel design, fabrication, and testing of low-cost, easily manufactured, open-source, underwater manipulators for use on light-duty remotely operated vehicles (ROVs) or autonomous underwater vehicles (AUVs). A novel modular, reconfigurable, cable-driven continuum manipulator for use underwater is introduced, which has high flexibility and inherent compliance. The second contribution is the integration of this continuum manipulator with an underwater vehicle to form the novel continuum underwater vehicle-manipulator system (continuum-UVMS). A kinematic model for the continuum-UVMS is derived to build an algorithm for the redundancy resolution problem. The third contribution is an open-source, user-friendly framework for bimanual teleoperation of light-duty UVMSs. This framework allows for the control of the vehicle, dual manipulators, and both end effectors using two low-cost haptic devices. The fourth contribution is a pattern search algorithm for planning optimal perching configurations for multi-armed UVMSs. The robot-environment stiffness matrix is derived using parallel robot theory and used to minimize displacement of the vehicle for disturbance rejection. The initial and optimized configurations are validated in a dynamic environment, demonstrating that the kinematic displacement is a reliable predictor for dynamic steady-state displacement.